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# The Seeds of Tornado Prevention


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## PREFACE

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# SECTION I

## INTRODUCTION

Tornadoes generally appear after severe frontal thunderstorms involving copious amounts of lightning.  Vonnegut (Reference 1) points out the insightful association made in a referenced 1840 comment by Peltier that “Everything proves that the tornado is nothing else than a conductor formed of the clouds, which serves as a passage for a continual discharge of electricity …”.  Figure 1 shows the designated oldest known photograph of a tornado (Reference 2) obtained approximately one-half century after Peltier's concluding comment.  As will be seen in subsequent description given here, Peltier's quoted one sentence elucidation is not quite correct but modern observations do show that tornado development does trail the peak of lightning activity (References 3 & 4).  And, despite the association of thunderstorm-generated-lightning and tornado occurrences, the fundamental origins/forming conditions of tornadoes are not yet fully deciphered.  For example, recent description of electrical features associated with tornadoes (Reference 5) presumably once developed, allows for conflicting reports of "remarkably intense lightning …" and the "absence of lightning in the storm".

Recent lightning-tornado association (Reference 3 & 4) is to be compared with previous description (Reference 6) of rare electrical activity near or within tornadoes.  Current emphasis is on the fundamental role of all possible parameters on determining a critical updraft feature even of the thunderstorm origin while leading possibly to any tornadic activity (Reference 7).  Such basic differences in attribution of “on or off” electrification in tornadogenesis accrues, undoubtedly, in part, to the need for coming together in not quite chaotic circumstance of a combination of tornado determining parameters/conditions.   The situation bears similarity with the anecdote of defining an elephant from different touches on disparate external parts --- despite one association (Reference 8) of the tornado funnel with an elephant’s trunk.

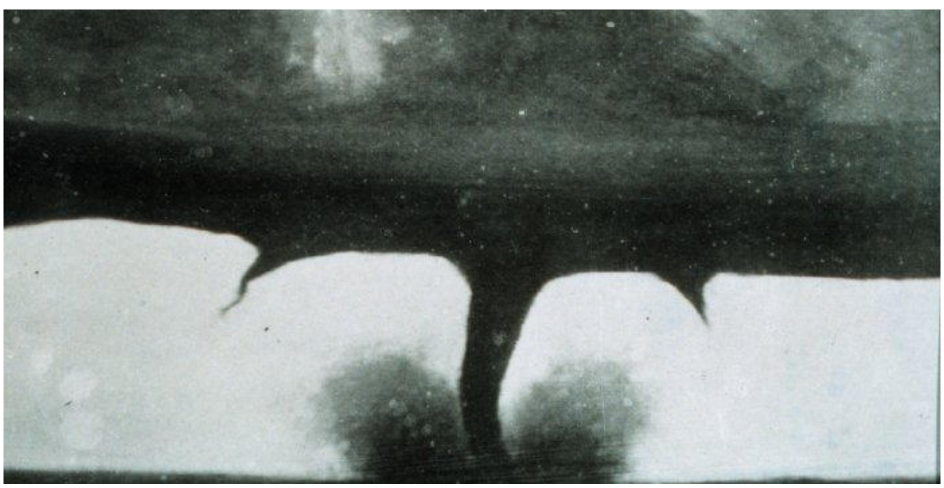

**Figure 1.  Oldest known photograph of a tornado, 28 August 1884, at location 22 miles Southwest of Howard SD, as obtained from the NOAA Photo Library Historic NWS Collection**

Here we first synthesize a series of events, based on previously reported tornadic studies, by which a tornado might be envisioned to originate --- no small feat because of the complexity of involved parameters--- and, then, propose a novel method of defeating such tornadic development at embryonic operation.

## SECTION II

## THUNDERSTORM/TORNADO ELEMENTS

Figure 2 illustrates the normal thunderstorm situation of a build-up of positive upper and negative lower charges in the thunderstorm cloud structure. The situation leads eventually to lightning strikes, in this chosen schematic case, being shown to initiate within the cloud (Reference 9) that, at thunderstorm stage, is in a low-pressure, multi-phase, (ionized) plasma/gaseous/particulate state. The vertical charge separation is thought to involve mostly hydrogen/hydroxyl/nitrous ion-associated water/ice molecule clusters or particles, proposed to generate the charges through strongly-convective ice particle collisions (Reference 7). In such charge generation process for establishment of the electric field within the thunderstorm cloud, a fundamental role is assigned to existence of a strong intra-cloud updraft, whose collisional charge generation process over-rides, at least, at first, the reverse flow of negative charge to the lower cloud level. In any event, the vertical charge separation is thought to develop in more complicated convective churning of the “vaporous soup” than simply being the result of an eventual gravitationally-determined lower heavier hydroxyl ion attachments as compared to higher lighter hydrogen ion ones. Strong friction forces are proposed to be associated with minute hail nuclei interactions. The buoyant force of the updraft is sufficient to support quite large hailstones or other graupel prior to their release. Cosmic radiation apparently contributes little to the process (Reference 10). Figure 3a is a more detailed elaboration of the charge build-up occurring within a thunderstorm “supercell” structure, also showing the importance of wind shear properties as part of the updraft in contributing to tornado development (Reference 11).

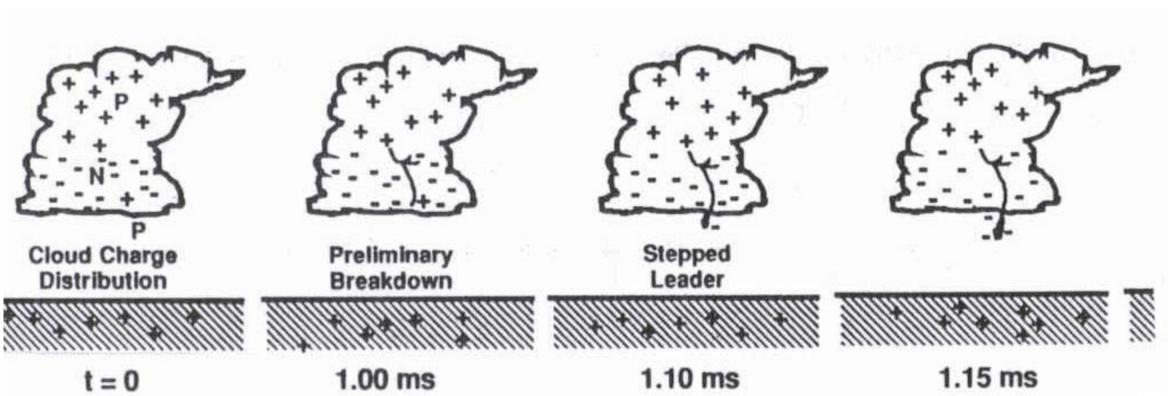


**Figure 2. Partial sequence of timed steps in a cloud-to-ground lightning strike, giving emphasis here to intra-cloud initiation of the lightning strike; time is in milli-seconds; see Reference 6**

The build-up of vertically separated charge densities within the potential thunderstorm proceeds until dielectric breakdown of the cloud resistance occurs and lightning strikes are produced, as indicated in Figure 3b.

Intra-cloud strikes are of special interest in modern researches that show essentially no correlation with cloud-to-ground strikes (Reference 3 & 4). Here, we focus on the intra-cloud strikes for the additional reason that such strikes produce localized cylinders of ionized particles, particularly, of hydrogen and hydroxyl ions, which then are accelerated as charge carriers within the otherwise global electric field of the thundercloud structure.

A role for consideration of the smaller, "unseen" population of molecular elements has been attributed to Rathbun in a later comprehensive analysis of electrical influences on tornadic behavior (Reference 12). The hydrogen ions are accelerated downward and the hydroxyl ions, up, even if attached to water or other molecular clusters. The easier flow of hydrogen ions downward produces re-combination to $H_2O$ molecules and, thence, to ice or water, with an approximately twenty times greater exothermicity for the ionic re-combination as compared with the molecular condensation. The liberated heat at the lower cloud level should contribute significantly to added strengthening of the updraft, otherwise found reasonably difficult to account for, temperature-wise, only on a condensation basis (Reference 1 & 12). Greater influence on the mixed vapor flow, molecular-collision-wise, is produced by the heavier hydroxyl ions that are driven upwards to effect their re-combination at the upper cloud level in the global electric field. Thus, an electrically-driven addition to the updraft is produced with important temperature and pressure components. The encompassing cloud and charge carriers operate as an electrostatic motor (Reference 13).

An essentially vertical lightning strike produces a radial distribution of ions traveling upwards and downwards on the cylinder circumferential surface surrounding the post-strike "centerline", very probably, having peak distribution within a particular radius increment. Perhaps there is a vortex-type screw character to the lightning strike, though as yet only referenced (Reference 12) to an electrodynamic theory proposed by Rathbun. Subsequent pioneering laboratory experiments to study tornado characteristics have been performed by way of demonstrating the character of electric discharges occurring inside of vortex-stabilized vertical arcs (Reference 12 & 13) that have provided indication of updraft enhancement of lightning strikes. We would term these experiments, along with most of the referenced information obtained until the present time, as post-tornado characterization. Aircraft measurements of lower cloud positive charges have been attributed to the "deposition of positive charge by lightning" (Reference 14).

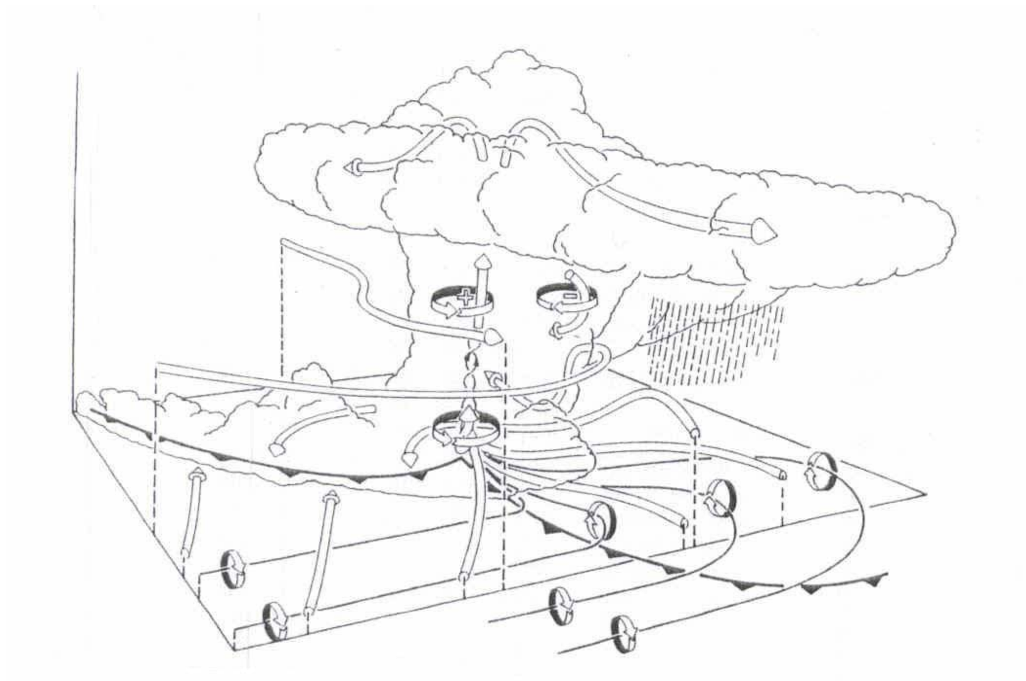

**Figure 3a.  J. Klemp three-dimensional schematic illustration of horizontal wind velocity influence on tornado development, including charge separation, as utilized by Bluestein (Reference 11)**

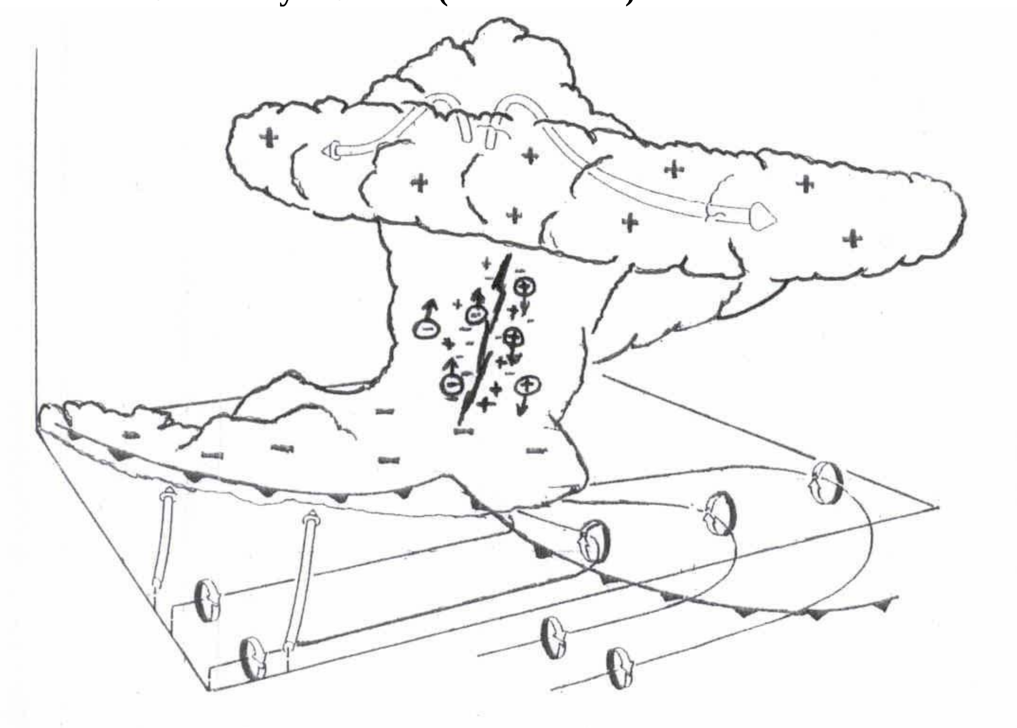

**Figure 3b.  Adaptation of Figure 3a to show an intra-cloud lightning flash producing  charge carriers to activate the thunderstorm "motor" in pre-tornadic development**

Now, the description given above applies only for a single intra-cloud lightning strike among an increasing number associated with greater thunderstorm strength. The single vertical "motor cell" is among many distributed side-by-side in the super-sized thundercloud --- and these vortex-type cells repel each other with a force proportional to whatever vortex component of strength may have been acquired. Again, because of previous interest in lightning-associated tornadic activity, research study of the association has indicated no reason for repeated strikes to occur within a once struck vortex (Reference 15). However, the mechanism that is being proposed here for an individual cell to achieve tornado status is one of repeated lightning strikes having to occur within the same cellular zone of an earlier strike. Such improbability relates to the observation of tornado development being particularly associated with extensively repeated lightning activity within a given region (Reference 3 & 4). And, along the way towards tornado development is the tell-tale beginning of intensification of localized updraft experienced at the lower cloud surface of the thunderstorm, thermally-assisted by the (downward) arrival of hydrogen ions for re-combination/condensation.

Thus, in summary, intra-cloud lightning is a necessary but not sufficient requirement for tornado initiation. The need for multiple strike activity within an individual pre-tornadic cell relates to the relative rarity of tornado occurrences. Tornado generation is attributed to: [1] sufficient charge separation in the thunderstorm, with accompanying internal atmosphere, to generate copious lightning strikes; [2] repeated intra-cloud strikes within a developing tornadic cylinder for thermally-assisted build-up of vortex strength; and, [3] re-combination of deposited positive charge at the lower cloud surface for temperature rise plus heavier negative ion collisional flow upwards to contribute vertical pressure --- all aided by lateral wind considerations (Reference 11).

## SECTION III

## CHARGE RECOMBINATION/CONDENSATION

A tornado, however formed, contains much less energy than the thunderstorm that produces it. Modern evidence for tornado occurrence following significant lightning activity (Reference 3 & 4) is shown in Figure 4. The strong correlation has led to suggested orbital lightning monitoring as a possible tornado warning system. However, while elimination of the global-type charge separation that occurs in thunderstorm development is "out-of-the-question", there is opportunity of interfering with tornado initiation caused by lightning "charging" of potential vortices. The basic idea is to effect both lightning suppression and/or recombination of lightning-initiated charges by supplied nanometric fly-ash-like particles (Reference 16) put into the embryonic updraft zone, located just below the negatively charged lower cloud level.

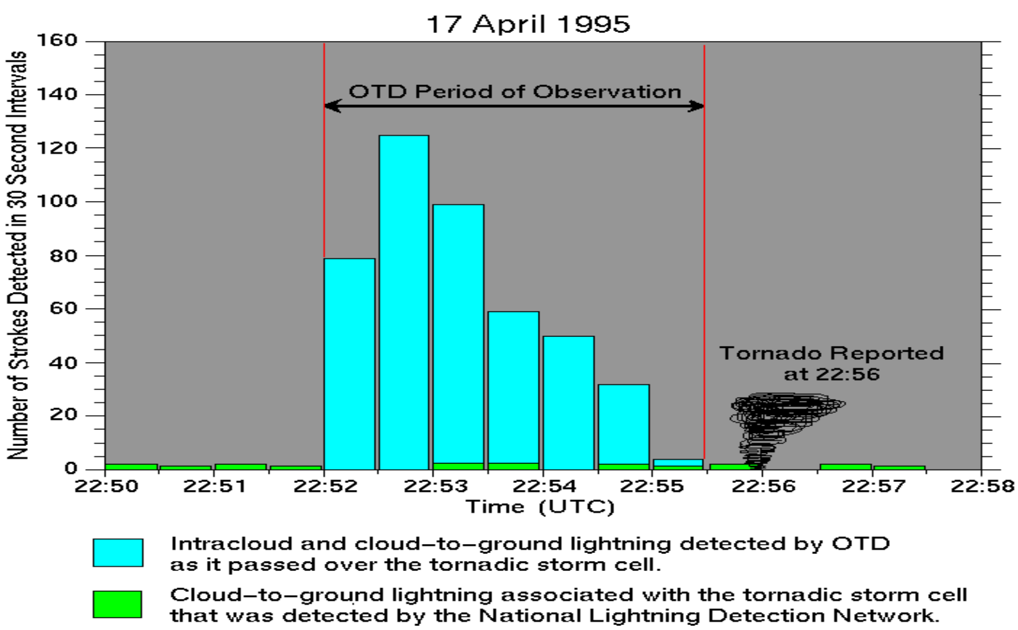


**Figure 4. Optical transient detector (OTD) plot reported by NASA Space Science News, as obtained from orbital observations made over a storm in Oklahoma. "OTD registered a sharp increase in lightning flashes as the storm system built, and as clouds rose, then a sudden drop as the system collapsed and spawned a tornado" (References 3 & 4)**

As a start, the insulating character of the ceramic constituents of fly-ash particles should contribute to increase of the dielectric breakdown strength of the intra-cloud atmosphere. Also, the low density and small size of the suggested particles should promote their having an important significant lifetime in the intra-cloud chamber, as presumed useful to effecting ion recombination and subsequent phase transformation.

The proposed method of tornado prevention by a cloud seeding procedure is novel for several reasons: [1] essentially lighter-than-air nanometrically-sized particles are involved; and [2] the particles are to be injected into the early updraft development of the lower cloud level. Of course, it has been known for the last ten years that cloud seeding has been accomplished quite effectively for hail suppression (Reference 17). Hail is known to be a by-product of the storm systems that produce tornadoes and such seeding has been utilized to effectively reduce ground level damage through reduction of hail stone sizes. Such alteration of hail characteristics that has been achieved on a large scale, effectively altering cloud energetics even at a scale near to tornado spawning thunderstorms, provides encouragement for the current proposal. In contrast to other rain-making cloud seeding activities, both hail suppression, as referenced here, and the proposed charge recombination/condensation mechanism involves super-saturated atmospheric conditions that need only relatively much smaller particles, even suggested nanometrically-dimensioned ones, to effect charge re-combination and thence molecular condensation. The smaller particle sizes relate to the important consideration of being able to disperse a sufficient number of particles to influence the properties of a sizeable cloud structure. Under such severe atmospheric conditions, the finer aspects of effective advantage through top-down cloud seeding also to involve epitaxial aspects of utilizing (heavier) silver iodide particles seem relatively unimportant, although such consideration is not discounted among potential low-density candidate particle materials.

The basic idea is to foster recombination of separated ionized hydrogen and hydroxyl constituents from water, along with gaseous water molecules, into water/ice particles in the heavily supersaturated cloud formations presaging possible full tornadic activity, thus, producing significant energy dissipation in the formation of condensed products and consequent, undoubtedly heavy rain or hail, instead of lightning strikes and destructive wind power. The main consideration for accomplishing the task involves a form of "cloud seeding" --- done in a new way with new particle considerations, as follow:

(i) To make important contact, first, with the particular constituent of a heavy concentration of hydroxyl ions at the lowest cloud surfaces, the cloud seeding is to be initiated by liberation of appropriate nanometric, or near-nanometric, sized particles below the lower cloud levels.

(ii) Something-like nanometric-sized fly-ash particles (that are hollow ceramic cenospheres, that unfortunately are normally of larger 30-300 micrometer size) would seem to be ideal from a desired "lighter-than-air" property in that an important concept in this proposed consideration is that, if tornadic development is imminent, the particles would be dragged or pulled upwards, in the convectively-stirred up-draft presaging tornado occurrence, thus going through the clouds from the bottom-up while serving as particle nucleation/growth sites, first, for hydroxyl ion absorption and then, further up in altitude, hydrogen ion reaction/nucleation to form hail or rain.

(iii) Perhaps, a weak positive charge state could be added to such particles, first, to help prevent their own agglomeration and then, when appropriately dispersed, to help in promotion of first stage hydroxyl ion adsorption. As an aside, if only positively charged particles, near to being lighter than air, were liberated simply to combine with the hydroxyl ions, the advantage of gaining dissipation of the very appreciable ionization potential energy in forming water or hail particles would be lost.

(iv) The proposal of employing nanometric particles in order to accomplish tornado defeat is important for at least two size-dependent reasons: (a) such small size is in the presumed smaller, or smallest, particle regime theoretically capable of nucleating water droplets under large supersaturation conditions; and, (b) there is the more practical consideration of being able to carry/disperse "billions and billions" of particles during conveying flight.

## SECTION IV

## SUMMARY AND DISCUSSION

"If this nation had a foreign army do to us in one year what a tornado can do to us in one day we would use every means possible to fight it". This statement was made approximately one year into this project to emphasize the need for the United States Government to take an offensive approach to dealing with tornados and their damaging influences on DOD bases, infrastructure and citizens.

Present day tornado research and monitoring activity is largely defensive, in being focused on the development of advanced, improved, warning systems because, for one reason, of the intimidating thought that the supercell system is too large in physical size/energy content to be deterred. The very idea of manipulating or effecting change to a weather system has been looked upon by some as hardly more than "tilting at windmills". However, due to the accumulation of an overwhelming number of practical weather modification programs, which primarily involve cloud seeding activities aimed at enhancing precipitation or mitigating hail damage, in more than 24 countries and 66 programs in 10 states across the country, the National Academy of Sciences (Reference 18) recently recommended that a coordinated national program be developed to conduct a sustained research effort in the areas of cloud and precipitation microphysics. The program is recommended to be implemented using a balanced approach of modelling, laboratory studies, and field measurements designed to reduce key uncertainties. The program intention is help to meet the ever-increasing demands for water supply and to provide ways to reduce weather-induced destruction and loss of life.

The Glenn-Armstrong theory for tornado prevention is focused on a very localized region of a super cell that is in a pre-tornadic state of development, and not as a panacea after a tornado has been generated. Tornado formation is rare. Only ~30 percent of meso-cyclones actually produce tornadoes. The development of a tornado from a super cell appears to be a very particular process of step-by-step climbing up a so-called "energy ladder". The overall energetics involved in the successive super cell building events include ice particle collisions leading to generation of a global electric field, then, followed by intensely-localized lightning strikes associated with tornado formation. The lightning, of specially repeated intensity and spatial localization, adds, via several mechanisms, to significant updraft enhancement and tornado formation. The total process occurs over a limited time period. A solution proposed here is to "surgically inject billions and billions of nano-particles" into active, or imminently active, lightning-generated "electrostatic motor regions" so as to promote recombination of sequentially generated hydrogen/hydroxyl ions in the intracloud chamber. The suggested lighter-than-air particles would be injected through the clouds from the bottom-up to serve as particle nucleation/growth sites, first, for hydroxyl ion absorption and then, further up in altitude, for combined hydrogen and hydroxyl ion reaction/nucleation to form hail or rain. The particles would especially be available for recombination of the newly-lightning-created free ions in the intra-cloud chamber. This method of interfering with the "electrostatic motor" operation tracked to imminent tornado genesis only needs to be done until the super cell starts to naturally dissipate by other means and the processes conducive to tornado formation are no longer present!

## SECTION V

## CONCLUSIONS

A novel method for defeating tornadic development at the embryonic stage has been proposed and described. The Glenn-Armstrong Theory for tornado prevention focuses on a very localized region of a super cell that's in a pre-tornadic state of development and involves the bottom-up seeding of the super cell with billions of nano-particles, e.g., fly-ash. The suggested lighter-than-air particles, recommended in part for added lifetime in the intracloud chamber, would be injected upwards through the lower cloud level to serve as acceptable particle nucleation/growth sites, first, for hydroxyl ion absorption and then, further up in altitude, for combined hydrogen and hydroxyl ion reaction/nucleation to form hail or rain and, thusly eliminate/reduce tornado formation.

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